Weather Note

A RADAR ECHO CONFIGURATION ASSOCIATED WITH A SERIES OF WATERSPOUTS

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ABSTRACT

The appearance of the echo on the WSR–57 PPI scope during the occurrence of a series of waterspouts near Daytona Beach, Fla., is described. The main features were a hole in the center of the echo and a very steep reflectivity gradient in a V-shaped notch on one edge of the echo. Photos and an eyewitness account are included.

1. INTRODUCTION

On July 14, 1960, a series of waterspouts occurred between 20 and 30 mi. from the WSR–57 radar located at Daytona Beach, Fla. This note describes the pattern of the PPI scope echo associated with the waterspouts. While a hard protuberance occurred which corresponds with the usual, but varied, tornado-echo peripheral phenomena, another feature of an unusual character was also observed. A hole was present in the approximate center of the echo. This hole was not observed to evolve from a hook or finger, and does not correspond to a "doughnut" echo feature.

Because photographic equipment was not available, and the antenna elevation drive motor was inoperative, with the antenna secured at +1° elevation, RHI data could not be obtained.

The WSR–57 is an S-band radar with peak power of 500 kw., short pulse of 0.5 microsec., and pulse length 500 feet, with which the pulse repetition frequency is 658 pps. The maximum range is 100 n. mi. when operating on short pulse.

2. DESCRIPTION OF OBSERVATIONS

RADAR OBSERVATIONS

At 1555 EST, on July 14, 1960, the Sanford Naval Air Station (NRJ), 30 miles south-southwest of Daytona Beach (DAB), reported a funnel cloud from a large cumulonimbus, bearing 085°. The radar antenna was scanned over the area, but equipment trouble developed, and the radar was not working properly until 1620 EST, at which time a close examination was made. An unusually large mass of echo was present in the area. The cell with which the funnel was most probably associated was selected, the scope off-centered at 155°, and expanded on the 50-n. mi. range. The most prominent feature at that time was a hole in the center of the large cell, bearing about 156°.

The radar was operated on short pulse with iso-echo turned on, and observed at various settings. Iso-echo presentation drew attention from the hole mentioned previously to a V-shaped notch on the north-central edge of the echo, where the gradient was extremely steep. The echo was approximately 10 n. mi. wide, and 40 n. mi. long, oriented southwest to northeast. The hole at 1620 EST had been 1½ n. mi. in diameter. At 1642 EST it had

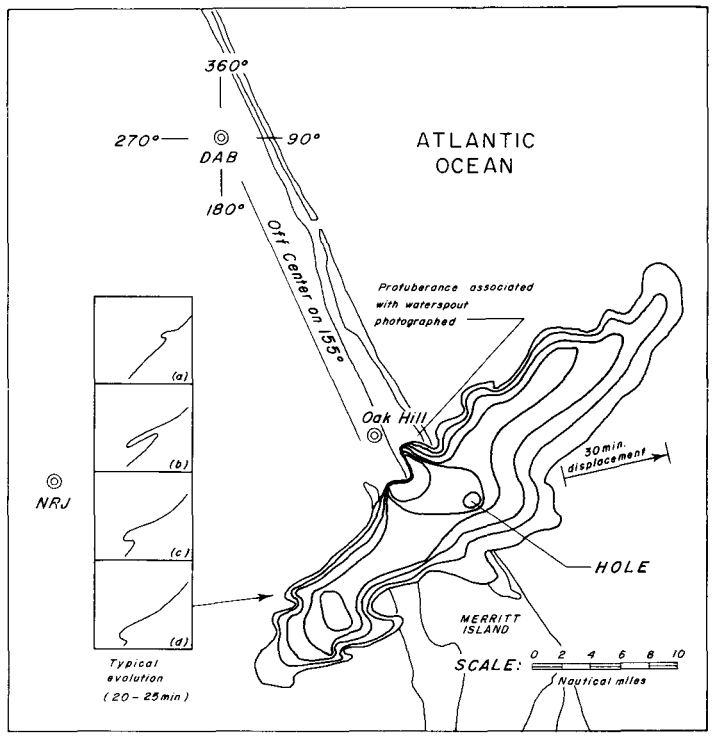

FIGURE 1.—Trace of PPI scope echo superimposed on map showing Daytona Beach (DAB), Sanford Naval Air Station (NRJ) and Oak Hill. Radar was on short pulse (0.5 microsecond) 50-n. mi. range, off-centered at 155° and expanded, STC on. Time of sketch 1642 EST, July 14, 1960, about the time of the photograph shown in figure 3.

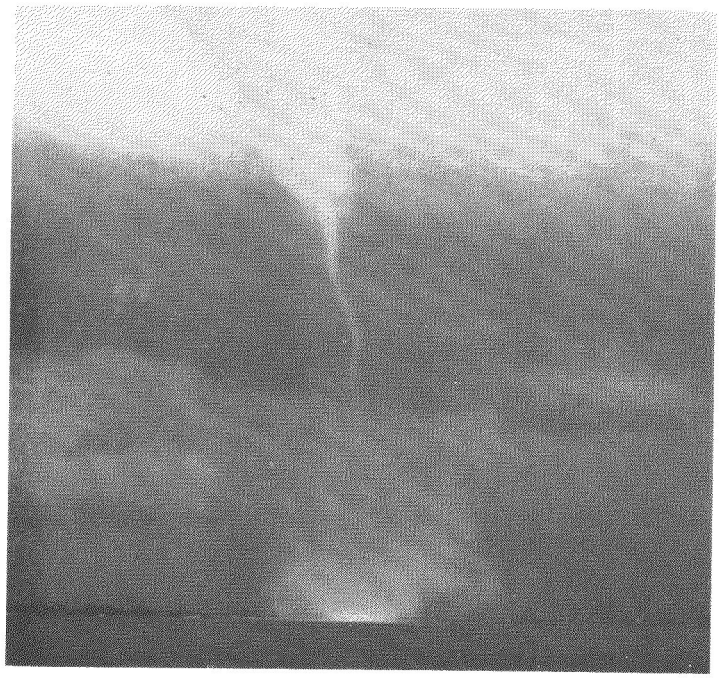

FIGURE 2.—Photo taken at 1610 EST, July 14, 1960. Waterspout is about ½ mile distant on a SSE bearing. (Photo courtesy Mr. Cal Dietz, Oak Hill, Fla.)

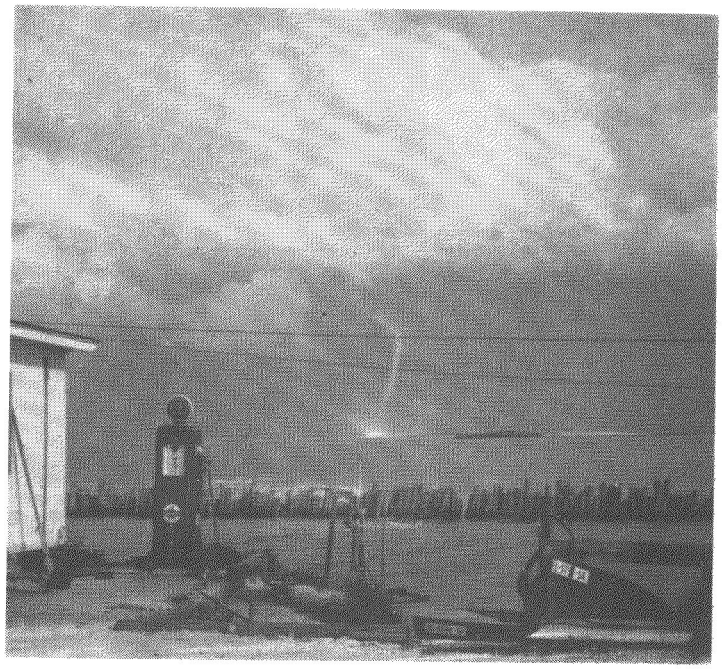

FIGURE 3.—A second waterspout, photographed from the same location as figure 2, at 1638 EST. It is about 2 miles distant on a SE bearing. (Photo courtesy Mr. Cal Dietz, Oak Hill, Fla.)

moved east-northeast at a speed of 14 kt., and the diameter had reduced to 1 n. mi. Several protuberances were observed to develop on the north edge of the echo, and move southwest along the edge of the echo. A tracing, figure 1, was completed at 1642 EST. The hole moved along with the echo, staying in the center, until it filled shortly after the tracing was made.

The greatest reflectivity, approximately 2×10^5 mm.^{6} m.$^{-3}$, or a theoretical rainfall rate of about 4 in. hr.$^{-1}$, was found in the protuberance northwest of the hole. (This value was determined by a maximum of 52-db. attenuation on short pulse.) Eyewitness accounts of the first waterspout relate that water drawn upward by the spout was spraying out above the bend. This may have contributed to the high reflectivity and the steep gradient found in the area of the strong protuberance. Water and spray which were probably carried only as high as the cloud base, judging from a photograph and observed cumulonimbus bases of 2000 to 2500 feet at DAB, would have been well within the half-power points of the radar beam. The reflectivity gradients indicated on the tracing are qualitative approximations only, from notations and markings on the original tracing. There was little change in the size of the hole as iso-echo attenuation was increased, i.e., the gradient was sharp, as in the notch.

The echo was solid about the hole, and the iso-echo gradient steep; therefore the circulation could not be ascertained. However, the protuberances did move southwestward along the northern side of the echo, while the less intense, more rounded ones on the southern side moved northeastward. Motion along the echo boundary seems to imply cyclonic circulation about the central portion containing the hole, and also around the strong core in the southwestern extremity of the echo. At the time of the tracing, the strongest protuberance was about 25 n. mi. south-southeast of Daytona Beach, and about 2 to 3 n. mi. southeast of the town of Oak Hill.

VISUAL OBSERVATIONS

Mr. Cal Dietz, owner of LeFiles Fishing Camp at Oak Hill, about 27 mi. southeast of Daytona Beach, and ½ mi. east of the center of Oak Hill, observed the formation and dissipation of two waterspouts, and obtained a series of Polaroid photos of the phenomena, two of which are included in this report (figs. 2 and 3). Figure 2 shows the full development of the first spout. Figure 3, the only picture obtained of the second spout, shows it at full development. Figure 3 was taken within 4 minutes prior to the time the radar echo sketch was completed, and thus coincides with it almost exactly.

Mr. Dietz stated that the first funnel began forming 1 mile east-southeast of the fishing camp, over an island in the inland waterway at about 1545 EST, moved west-southwest about 5 to 10 m.p.h., going inland and breaking up just south (400 ft.) of the camp about 1620 EST. The second spout formed over an island 2 mi. southeast of the camp about 1620 EST, also moved west-southwest, and broke up over a small island at about 1645 EST. He further stated that no rain fell at the camp, but that heavy rain could be seen from east through southwest, south of the waterspouts. The base of the first waterspout was estimated to be 150 feet in diameter, with the core 10 feet in diameter, sheath 60 feet in diameter, and height 500 feet. This spout produced a wake of about 4

feet, which broke over the pilings shown in figure 3. Both waterspouts developed near right-angle bends in the funnel.

The waterspouts were visible from the Daytona Beach FAA Tower, and were also reported by several pilots and the public in the vicinity of the waterspouts.

3. DISCUSSION OF OBSERVATIONS

It is believed that the hole in the echo is more than coincidental, and that it results from the major and central vortex of the "tornado cyclone," or funnel-producing cloud structure, the characteristics of which are summarized from several radar and mesoscale synoptic analyses by Fujita [2]. The hole phenomenon in connection with tornadic activity as shown on radar has been observed before, and is best documented by Bigler [3], who states that the hole "probably is caused by the centrifugal force of the tornado circulation removing hydrometeors from the center of circulation." The present observation might be explained similarly, though in this instance the hole definitely appears in the large central vortex of the tornado cyclone cloud structure, and is approximately 5 mi. distant from the surface waterspout.

PULSE-LENGTH DISTORTION

It is emphasized that the small waterspout column itself is not expected to be seen as a hole on radar even in absence of hydrometeors, due to pulse-length and beam-width effects. The minimum detectable diameter and minimum range separation of targets for the WSR–57 radar on short pulse is probably a little more than 250 feet, and is larger unless the column is vertical through the entire beam thickness. All but the most exceptional waterspouts have a diameter of less than 250 feet [4].

Detection and presentation as a projection form can be reasonably expected then, only when and where the waterspout occurs outside the "mother cloud." The pulse-length effect on the cyclone vortex would be to "fill it in" on the near side by half a pulse length.

BEAM-WIDTH DISTORTION

Beam width distortion of a point target (which a waterspout outside its mother cloud may almost be considered) for the 2° beam and 0.5-microsec. pulse length at 30 n. mi., results in an elongated echo roughly 100 yards in range depth, and 1¼ mi. long, oriented perpendicularly to the beam. These combined effects tend to exaggerate the waterspout projections, and reduce the size of the cyclone vortex; i.e., the targets producing the projection type echoes are expected to be smaller than the corresponding echo while the vortex hole is larger than the radar scope indicates. Battan [5] has discussed pulse length and beam width distortion at some length; the interested reader is referred to this source for more detailed information.

TYPES OF VORTICES

Fujita's [6] recent analysis of a somewhat comparable tornado situation, i.e., where a series of tornadoes occurred attendant with and at a distance from a larger rotating mother cloud, found that the tornadoes were of the rope-type when located 2 mi. or more from the center of the rotating cloud, and of the cone-type (larger) when nearer the center.

If the observations reported here and the studies cited are generally true, it seems probable that those vortices of the rope-type (as almost all waterspouts are) would be displayed on the radar only when occurring at a distance from the central vortex, and when outside or near the edge of the mother cloud, while the central vortex should normally be displayed when occurring within a range where the beam has a thickness of less than about 25,000 ft.—for the WSR–57 radar, about 90 mi.

The transfer of cyclonic rotation and energy over the distance from the central vortex to the surface waterspout is not clearly understood, and is not apparent from observations, radar or visual, except that the elbow bend in figure 3 indicates the beginning of the horizontal tubular cyclonic rotation, which most likely extends to the central vortex (the hole), and then vertically. On the other hand, it may result from a separate secondary peripheral circulation. Figure 3 illustrates that the smaller rope-like vortices exhibit sharp 90° changes in orientation, as is frequently observed [4, 6], which together with vertical beam-width effects and range relationships probably explain the main vortex and external waterspout funnel being seen at the same antenna elevation.

Cyclonic circulation of the whole echo, or possibly cells of the echo, is borne out by movement of projections along the edge of the echo. This phenomenon has been observed before in connection with tornadoes, and is documented by Bigler [1] and Fujita [2].

4. PREVIOUS RADAR OBSERVATIONS OF SIMILAR PHENOMENA

At this station there have been several instances in which a clear hole was observed in the center of a well-developed thunderstorm echo. In at least two instances pilots reported funnel cloud activity in connection with these cells. In neither case was a definite hook or finger observed on the radar, although hard protuberances of varied shapes were observed.

At 1835 EST on June 19, 1960, a pilot reported a funnel cloud over Lake Monroe, about 25 mi. southwest of Daytona Beach. The area was searched, and though no hooks or fingers were observed, broader protuberances were noted on the edge of the echo, as well as a hole in the center of the echo. The scope was not off-centered in that instance, but RHI observations were possible. On RHI the hole was observed to extend to 35,000 feet, tapering off in the top portion, with the top of the echo at 45,000 feet. Bigler [1], in a discussion of four radar observations of tornadoes in Texas, Oklahoma, and Massachusetts, states that "the tornado cyclone on radar may extend to 30,000 feet, and is surmounted by a ridge of echo." The hole discussed here was initially observed at 1835 EST,

bearing 206°, range 20 mi., and moved to 215°, range 18 mi. by 1850 EST, dissipating soon thereafter. During the period observed, the hole held to the center of the echo, and on the RHI scope presented an appearance similar to a sharpened pencil pointed upward.

5. CONCLUDING REMARKS

Radar operators observe holes in echoes, as discussed here, with some frequency without known funnel activity, possibly more frequently along the Gulf Coast. It has been noted in radar reports that Brownsville and other WSR–57 stations have reported these holes in connection with known or suspected funnel activity.

Some of these holes result from random arrangements of several cells—especially cells beyond about 60–80 mi. for the WSR–57. Others may coincide with unobserved or unreported funnels. The correlation then, between holes of the type reported here and funnel activity, may be vague. However, it seems that the feature deserves serious attention since, when funnel activity is occurring, it should be detectable more often than the waterspout or tornado projections. Also, hard protuberances, more generally accepted as indicators of funnels, occur with even greater frequency, apparently in some instances to the extent of appearing as the classical hook [7], without funnel activity.

Several months' experience with the WSR–57 radar at Daytona Beach indicates that within our range of surveillance funnel activity is at present quite difficult to "see" due to the large masses of echo on the scopes, caused by both the greater areal cloud coverage prevalent in this region, and the greater detection capability of the WSR–57 radar.

In terms of the scope displays, if some attendant features, i.e., reflectivity structure, or critical parameter values associated with echo holes, can be found, it may be that the real cyclone vortices, can be distinguished on the radar in a practical way, from holes appearing randomly. This would be of great importance.

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Weather Note

EXTENSIVE AREA OF PERSISTENT STRATUS AND FOG IN GREAT PLAINS November 27–December 2, 1961

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An area of stratus and fog which extended roughly from western Texas to eastern Nebraska and western Iowa persisted from November 27 to December 2, 1961, a period of almost a week. The areas shown in figure 1 enclose regions where ceilings were below 1000 ft. and/or visibilities below 3 mi. on the dates given. Clouds and fog formed and persisted in a modified polar continental air mass which became cut off and stagnated.

The air mass moved south behind a cold front which entered the Northern Plains on November 26 and spread to the Gulf Coast on the 27th. Stratus and fog formed in the cold air over a large area of the Northern and Central Plains and the upper Mississippi Valley. During the night of the 27/28th the area shrank to that shown by the solid line in figure 1.

A surface ridge formed from southwest to northeast over the area and moved slowly southeastward. A broad ridge aloft moved slowly eastward during the same time (fig. 2). The low-level flow pattern was such that it left a large mass of air relatively undisturbed in and along